ART. V.—THE PEDUNCULAR TRACTS OF THE ANTHROPOID APES.

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NUMBER I.

THE attempts of biologists to refer the origin of the human species to a progressive development from an extinct and thus far problematical anthropoid ape, have induced both the defenders and opponents of the doctrine of evolution to make a careful study of the existing human-like apes of Africa and Asia. It was but natural that those in favor of this doctrine should lay greater stress on the resemblances, and that their opponents should attach more weight to the differences found between man and his nearest allies; but, on the whole, this controversial turn of the discussion was exceptionally a source of profit: for it induced numerous observers to accurately study the debatable points, and thus enabled them to correct the errors into which the earlier anatomists had fallen.

It cannot be denied that the general result of these inquiries has been to verify the proposition of Huxley, that the differences between the anthropoid apes and the human species are less than the differences between the former and the quadrumana next below them in the scale. One line of defense after another has been erected by the opponents of the evolution doctrine, and one after another has been swept away! The organ of the mind was the last conservative stronghold, and here the contest waged most bitterly within a very recent day.

At first it was maintained that man alone had a considerable cerebral overlap; it was then demonstrated that not only the anthropoid but common apes had as considerable an overlap as some human specimens. Then it was asserted that man alone had a posterior cornu of the lateral ventricles, and a hippocamp at its floor. Now it is well established that not only the highest but the lowest monkeys—such as the lemurs—have both cornu and hippocamp, and that these characters are not even limited to the quadrumana. It was next claimed that in man alone is the island of Reil completely covered by overlapping convolutions; and when this was shown to be an error it was as gratuitously asserted, and for a time even accepted by the evolutionists, that man possessed, and the anthropoid did not possess, gyri on this area. The existence of such sulci and gyri in the brains of the chimpanzee and orang-outang, and even the non-anthropoid baboon is unquestionable.*

Unable to demonstrate any fundamental difference, observers like Bischoff have resorted to a comparative study of the gyri on the cortical convexity, and established diagnostic marks on the presence or absence of transition gyri, of an occipital operculum, or an inferior frontal convolution. As soon as the discussion took this turn, a number of monographs on the cortical gyri followed each other in rapid succession. Huxley, Barkow, Bischoff, Broca, Gratiolet, Hamy, Vrolik and Van der Kolk, Marshall, Rolleston, Turner, Vogt and Wernicke have dealt more or less exhaustively with the gyri of the chimpanzee and orang-outang, while Pansch, of Kiel, has now furnished that desideratum, a description accompanied by photographs of the cerebrum of the gorilla. Among the permanent results of these inquiries, our present perfected knowledge of the human gyri and their variations is the chief.

But perhaps the tendency of all these writers has been too exclusive, attaching an unduly preponderating importance to the gyri *per se*. If the relations of mammalian families were to be made even partially dependent on cortical resemblances, then the spider monkey, with his long prehensile tail and rudimentary thumb, would rank unpleasantly close to the human being; and Vogt † has shown with considerable humor that if the characters considered by Bischoff to separate man from the highest apes be the essential requisites of the human brain, then all that would be necessary were to melt the so-called "devil's ape" (Ateles Beelzebuth) and "Capuchin-ape" together to constitute the lord of creation!

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* "Contributions to Encephalic Anatomy. Part V.: The Organology of the Island of Reil," JOURNAL OF NERVOUS AND MENTAL DISEASE, January, 1879. aut.

† Carl Vogt: *Lectures on Man.* English edition. Published by the Anthropological Society, London. 1864.

The anatomy of the cerebral surface has therefore been carefully studied; but the same cannot be said of the structures and relations of the peduncular tracts. Either no reference is made to the latter or a general surface description is given. Such structures as have no assignable functional importance, as, for example, the *corpora mammillares*, have formed the chief subjects of discussion, while important features, such as the relative degree of development of the pons, the pyramids, the restiform columns, the nerve nuclei and the relations of the trapezium have well nigh been overlooked. This neglect is the more remarkable, as Meynert * has shown in his suggestive monographs, which have appeared during the last ten years, that the relations of the peduncular tracts and basal ganglia to each other, present well marked differences in different animals, and that the superiority of the cerebral hemispheres in man is projected in a corresponding predominance of the pes pedunculi, the pons proper and the anterior pyramids.

I shall proceed to present the results of an analysis of the peduncular tracts of two anthropoid apes, and to compare their characteristics, step by step, with those of the corresponding human parts.

The series of specimens on which I have based this description were obtained from two chimpanzees, both males. One of these was perhaps the largest specimen which has been kept in captivity, and had, judging by the development of its genitals, arrived at the age of puberty. The brain of this chimpanzee, when divested of its membranes and fluids, weighed grammes 389.86; there was some atypical asymmetry of the hemispheres, which had probably been related to the mental idiosyncrasy observed during life; and to preserve this appearance the brain was kept intact. The other specimen was obtained from an infant chimpanzee, whose age may have been a little over two years. It died of tuberculous meningitis, and the preservation of its softened nerve centres implied the use of alcohol for the first few days, after which the peduncular tracts were immersed in bichromate of potash, and a series of over four hundred transverse sections was obtained—the sections ranging from the decussation of the pyramids to the altitude of the corpore mammillares. One hundred and forty of these sections were selected for preservation. The methods employed were the same as those described in my article entitled "Contributions to Encephalic Anatomy" (Part I.), published in the JOURNAL OF NERVOUS AND MENTAL DISEASE for October, 1877. For purposes of comparison, I had at my disposal thirteen more or less complete series of sections from human pedunculi, as well as the tracts of an orang-outang, for whose brain I am indebted to Mr. Hermann Dorner, Ph. D., who also furnished me the bodies of the two chimpanzees referred to above. Other series from lower monkeys, such as the cebus, semnopithecus macaque, and baboon, I owe to the courtesy of Mr. Conklin, Superintendent of the Zoological Department of Central Park.

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* "Ueber Unterschiede im Gehirnbau des Menschen und der Saugethiere." 1870. — "Beiträge zûr Kenntniss der centralen Projection der Sinnesoberflächen." 1869.—"Studien ueber die Bestandtheile des Vierhugels, soweit sie in den nâchst unterhalb gelegenen Querschnitten der Brucke gegeben sind." *Zeitschrift fur wissenschaftliche Zoologie*, XVII. Band. See also "Contributions to Encephalic Anatomy," JOURNAL OF NERVOUS AND MENTAL DISEASE, 1877-78-79.

Before giving the results of my comparative measurements, I shall describe the coarse anatomy of the parts in question, and then take up the features distinctive of certain topographical altitudes in their order.

It may be remarked here that there is a considerable difference between the tracts of the two chimpanzees. The elder one, whose hemispheres were remarked as being more richly convoluted than those of the younger animal, had, to judge from the plastic elevation, better developed pyramids and olivary bodies than the latter. The nuclear elevations were also better marked; this was probably due to the difference in age.

There is no doubt that if my measurements had been taken from the older chimpanzee they would have compared more favorably with the human measurements.

The ventricular contours were studied on the series of transverse sections taken from the younger animal.

At the junction of the spinal cord with the medulla oblongata, the central canal is a vertical slit, which is asymmetrical in some sections, showing a faint tendency to send out transverse diverticuli, and becomes linear and regular in the altitude of the lower pyramidal decussation. Before the middle of this decussation, the canal as such is obliterated by a loose mass of cells, which easily falls out of the sections and leaves a laurel leaf shaped gap; where the mass is intact it in some sections shows the openings of one or two irregular sinuous channels. At the commencement of the upper decussation the canal is once more open and remains so.

From this point on the central canal begins to be approached by the posterior fissure of the medulla oblongata, becoming at the same time more slit-like. It joins the posterior fissure just above the pyramidal decussation very gradually, and is at first connected with the latter by a mere slit enclosed by the walls of the posterior fissure. The central canal has entirely merged into the fourth ventricle in the region where the hypoglossal nerve roots become most distinct. The *alæ* of the posterior half of the fourth ventricle are but feebly marked, and just behind the striæ medullares acustici, there is no demarcation whatsoever. In this respect the medulla before us contrasts markedly with that of the human being, but it must be recollected that this chimpanzee died of tuberculous meningitis, and that the incipient hydrocephalus present, obliterated the contours at the floor of the ventricles. A pathological proliferation of the ependyma was observed, and to this doubtless was also due the obliteration of the central canal alluded to.

The anterior half of the fourth ventricle exhibits well marked and broad *eminentiæ teretes*, and a deep *fossa cœrulea*, which however shows no color as in the *adult* human being. In the region of the quintus origin, where the ventricle begins to undergo its gradual transition into the aqueduct of Sylvius, and is covered by the *lingula cerebelli*, it is seven-sided, the broadest side being under the lingula, two arched sides with a deep slit between them correspond to the *eminentiæ teretes*, the smaller sides being lateral. The lower of the lateral walls begins to diminish and finally disappears, so that in the region of the *velum* behind the origin of the trochlearis nerves the aqueduct becomes five-sided, the angle of the pentagon being directed downwards. Still further on the remaining lateral walls disappear and the aqueduct is now an inverted triangle, which gradually changes to an arrow-head shaped figure in the region of the posterior corpora bigemina. In the altitude of the anterior pair it becomes slit-like and vertical, continuing thus until it opens into the third ventricle, where it has become more three-sided again. The transverse section of the aqueduct exhibits a wavy contour, corresponding to a longitudinal striation, termed *pectunculus* in the human brain by Arnold.

At the posterior end of the fourth ventricle, a not very well marked obex is observed, which is exclusively composed of white substance. It is in man sometimes composed of white and sometimes of both grey and white substance.

Aside from the results of pathological alteration, the aqueduct, fourth ventricle and central canal correspond to the most common form of these parts in the human species. It is well known that in the latter, there are numerous variations, the general type as indicated is represented in the anthropoid ape also.

On examining the base of the brain, we are struck with its close resemblance to that of a child, especially is this resemblance marked in the peduncular tracts. Behind the thick and well marked chiasm, which is rather broader relatively than the human, we perceive a long and thin infundibulum, to which a vertically flattened hypophysis is attached, of the same color, shape, and relative dimensions as in the human subject. The corpora mammillares are prominent and distinct from each other, being separated by a deep notch.

The crura are almost cylindroid, they have a bold convex contour, and are not irregularly bulged out by deeper ganglia as in lower animals. The pons is massive, presenting a beautiful double sweep of its anterior outline as in man, with a median notch, beneath which a deep *fossa cœca* is found. The posterior outline is straight, and beneath it a similar cœcal depression exists, exactly as in the human subject. The fibres of the pons entering the cerebellum by its middle peduncle are mainly directed backwards. In the larger chimpanzee the antero-posterior diameter of the pons is 19 millimetres, the transverse, measuring between the outer contour of the large quintus roots, is 28 mm. The pyramids emerge from the pons as well-marked half cylinders, each pyramid singly measuring 5 mm. across, a slender *ponticulus* (Arnold) runs over them at the point of exit from the pons. At a distance of 2.5 mm. from the posterior pons-border, the olivary eminence begins, and from this point on the pyramids become narrower and flatter, to expand again without regaining their previous convexity at the lower extremity of the olivary elevation; further on they gradually become narrower and narrower until they terminate superficially as sharp points; the contour of the pyramids together with the median fissure between them resembles a steel pen much more than the ventricular "calamus scriptorius." The distance from the pons to this superficial termination of the pyramids is 20 mm., and the decussation itself is concealed in the depths of the anterior median fissure.

The olivary body is as prominent as in the human subject and bears the same relations to its surroundings, it is well demarcated, convex and *lobulated*, being divided into three or four imperfect lobes, exactly as in man. Its length is 11.20 mm., its width 5 mm. The width of the entire medulla at this point, measuring from the outer contour of one vagus root to the other, is 18 mm.

At the point where the medulla oblongata has undergone a complete transition into the spinal cord, the latter measures in the antero-posterior diameter 6.30 mm., in the transverse 10.2 mm. All these measurements were taken from the brain after it had been preserved for six months in alcohol, and are consequently smaller than the measurements taken from the recent specimen would have been.

The nerve roots present nothing calling for special notice, being in every respect identical with the human nerve roots. It is noteworthy that the diminution which the medulla undergoes from before backwards is gradual and even, not sudden as in the baboon, ateles and cebus.

Taking these parts as a whole and comparing them with lower animals on the one hand, and man on the other, we remark as points possessed in common by man and his anthropoid relative the massive character of the pons, especially in its anterior third. In the larger chimpanzee the height of the pons — by which I mean its measurement taken vertical to the surface — is 14 mm. In this respect man and the anthropoid contrast markedly with all other animals. A second feature is the bold contour of the pyramids at their point of exit from the pons, and the size and lobulation of the olivary eminence. The existence of a well-marked olivary eminence, I may state here, is not necessarily an indication of a well-developed olivary nucleus. Meynert has evidently had imperfect specimens at his disposal, when he states that the baboon has a rudimentary olivary eminence, and the dog none. The eminence is present in the latter, and is well pronounced in the former; and in ateles it is as distinct and of as plastic a contour as in man, though occupying a relatively smaller area. On the other hand, the seal, for which animal Meynert claims an olivary body as well-marked as in the highest apes, has an eminence, it is true, but the olivary nucleus itself is not better—nay, not as well—developed as in the bear. The elephant has an excellently marked olivary eminence; but the olivary nucleus is of a very simple structure. Consequently the height to which the olivary *eminence* attains is no criterion for the development of the *nucleus* itself. A bulky but unconvoluted nucleus may be associated with as high an eminence as a very intricately convoluted one, and an eminence may be present where the nucleus itself is so small as not to have had any influence in producing it, so that the eminence may be entirely composed of white substance.

Even in monkeys, with as high a hemispheric development as semnopithecus, macacus and ateles, the anterior half of the medulla oblongata narrows down very suddenly in joining the posterior half. The suddenness of this reduction in mass is, as Meynert has shown, most marked in lower brains, and is therefore still greater in the dog and rabbit than in the monkeys mentioned. It is due to the presence in the anterior half, and absence in the posterior half, of a considerable amount of molecular nerve substance, as the same author has shown.

In the chimpanzee this animal feature is absent.

There is no trapezium in the chimpanzee: the predominance of the pons conceals the fibres of that body as completely as in the human being. Immediately behind the pons, on either side of the anterior pyramids, is a deep depression, as in the human species, and in this area no trapezium fibres can be detected.

Whether man and the anthropoids are the only animals in which the trapezium is concealed, I leave an open question. The same condition *seems* to be present in ateles.

The abducens and facial nerves make their exit from, around and through the posterior pons border, as in man. The relative position of these nerve roots to the pons shows that the latter extends as far posteriorly as the human pons. This is further shown by the distance between this border and the anterior extremity of the olivary eminence, which is relatively the same in both instances.

It must be here emphasized that the anterior end of the olivary eminence does not correspond to the anterior end of the olivary nucleus. The former does not reach the pons in any brain; the latter extends a considerable distance behind the pons fibres in the human being; its relations in the chimpanzee we will yet discuss.

Comparing the base of the chimpanzée's peduncular tracts with those of a well developed human brain, we observe that the pons is slightly less voluminous, and the pyramids flatter between the olivary bodies. There are, however, as great differences between the pons area of different normal human brains as between the lowest of the latter and the chimpanzee. Particularly in its anterior half does the latter's pons resemble the same part of certain human brains—in depth especially. On the other hand, I have not yet seen a human brain in which the pons was so thin on its *posterior* border as in the ape before us.

As to the anterior pyramids, these I have frequently seen to be as flat in man as in the anthropoid. As a rule, however, even here the notch separating the olivary eminence from the pyramid was deeper; but in one negro and in an epileptic imbecile I found, also, this as faintly marked as in the ape in question.

Taking the *ensemble* of the chimpanzee's tracts, whether as to their relative dimensions, the angles of incurvation dependent on the basi-cranial axis, or their general contour, we must say that they resemble the corresponding human parts much more closely than those of the baboon resemble those of the chimpanzee. The latter possesses several other features present in none of the non-anthropoids: that is, the massive prominence of the anterior extremity of the pons, its near approach, when the brain is regarded in situ, to the infundibulum (topographically), and the direction of the crura, which is at so steep an angle that, unless the parts be artificially stretched, they are almost concealed from view. These, like the corresponding features in man, are related to the basi-cranial conformation, and are therefore still more pronounced in the human species.

In the orang-outang the parts are very similar to those of the chimpanzee. We notice, however, a far more human-like appearance of the pons. While, on the one hand, its mass is not very much larger, it is more evenly distributed, and the posterior edge is not as attenuated as in both the chimpanzees examined. The demarcation externally, between the olivary elevation and anterior pyramid, is as imperfectly marked as in the other anthropoids; but on the lateral aspect of the medulla, it juts out much more prominently than in the latter. The disposition of the nerve roots is the same as in man, and the trigeminus does not appear to be as large as in the chimpanzee. The crura cerebri are more convex, and are separated by a deeper inter-peduncular notch than in the other human-like ape.

The dimensions measured on the hardened and shrunken specimen are as follows:

Width of chiasm	13	Millimetres.
Width of optic tract	5	"
Thickness of optic tract	3	"
Length of exposed part of crus cerebri	6	"
Width of exposed part of crus cerebri	12	"

Length of pons varolii	18.5	Millimetres.
Width of pons at quintus roots	28.	"
Length of anterior pyramids	17.5	"
Length of olivary eminence	13.	"
Distance of same from edge of pons	1.8	"
Diameter of medulla, measured from inner aspect of one auditory root to other	16.	"
Same at decussation	10.5	"
Diameter of pyramids at emergence from pons	6.3	"
Same in middle olivary altitude	5.5	"
Same, three millimetres below olivary eminence	4.5	"
Length of fourth ventricle	20.	"
Greatest width	15.	"

The elevations at the floor of the fourth ventricle are much better marked than was described to be the case with the younger chimpanzee. The *alæ albæ medialis* and *alæ cinerea*, as well as the obex, are very prominent.

We will now proceed to study the series of transverse sections from the younger chimpanzee.

In the altitude of the first cervical nerve roots, the transverse section shows the same general distribution of white and grey matter as in man. The anterior cornu is broad and contains from thirty to forty multipolar cells, the processi reticulares are thin but numerous, and the neck of the posterior horn is almost entirely interrupted by vertical strands. The gelatinous head of the posterior horn nearly touches the periphery of the cord, and there are but few ascending quintus bundles visible. The decussation of the pyramids is still in progress, and coarse decussated bundles interrupt the continuity of the grey substance here and there, while fibres are seen emerging from the inner aspect of the anterior columns as the transition from the last pyramidal to the uppermost anterior commissural fibres. The area of the posterior columns is very large, this is a markedly human* feature. If the entire area of the section be taken as 1.0000, the human will be found to be .2235 and upwards, in this chimpanzee it is .2219, in the cebus monkey .1382.

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* The area of this column in the upper cervical region is very small in reptiles and amphibians.

There is a greater discrepancy in regard to the columns of Türck; none of my human specimens show less than .0369, the chimpanzee measures .0295 and .0300, the cebus monkey .0243.

In the lateral columns, the human being measures .2710, the chimpanzee .1955, and upwards in other sections, the cebus .1463. Taking into account that the latter measurement is in part so high because of the deficiency of other tracts, and the presence of much molecular nerve matter, the real proportion of the three cases would be: human .2710, chimpanzee .1955, cebus .1140. It is well known that these tracts vary extremely in the human being. The section as a whole could be mistaken for a human one readily, and in distinction from those of lower monkeys, exhibits a human-like proportion of the diameters. Taking the antero-posterior diameter as 10, the transverse in the human being is 11–13, in the chimpanzee 11.3, in the cebus .15.

The area measurements obtained were made in the following manner: A drawing of the section was made whose correctness was ensured by repeated measurements. A glass plate with numerous small squares ruled thereon was then placed over the drawing and the number of squares and their fractions gave the required relative areas. Although the last two decimals are so fractional as to be of no special importance, yet as they were obtained in the computation I have given them:

TABLE A.

	Area of Lateral Column.	Area of Posterior Column.	Area of Turck's Column.
Man	.2710	.2235	.0369
Chimpanzee	.1955	.2219	.0295
Cebus	.1463	.1382	.0243

As we pass through the series we notice the same metamorphosis of grey and white matter as in the human medulla. The ascending quintus root is remarkable for its size, but does not exceed the limits of the human range, the caput gelatinosum is folded as in man, while in lower animals it is a simple oval mass (even in cebus). The histological characters are essentially human, and if I were to describe them and the coarser anatomical characters in detail, it would but lead to a repetition of the well known facts of human anatomy. It is noteworthy, however, that the anterior pyramids are proportionately defective as compared with those of man.

The fibres of the motor decussation occupy a much larger area in man, and as the pyramidal fibres which are still vertical in this altitude are also more voluminous, it results that, with the same configuration of the grey substance, the vertical (antero-posterior) diameter of the human medulla is relatively greater. Taking the transverse diameter as a standard of 10, the antero-posterior is 9.2 in man, 8.8 in the anthropoid.

The nucleus cuneatus is larger in the chimpanzee, while the nucleus gracilis is of the same dimensions and as scattered as in the latter.

The measurements of sections from the altitude of the superior decussation, taking the entire area as 1.0000 are as follows :

TABLE B.

	Area of Pyramid.	Area of Posterior Column.	Area of Gelatinous Cornu.	Area of Nucleus Cuneatus.
Man	.3098	.1032	.0647	.0283
Chimpanzee	.2384	.1846	.1000	.0384
Cebus	.1093	.1406	.1718	.0468

While at the level of the first cervical nerve roots the posterior columns of the anthropoid ape were equal to those of the human being, we now observe a marked difference, the chimpanzee possessing a much larger area in the present altitude. Now, this difference must be due to some quantitative difference in the distribution of the fibres, and I find strong reasons for considering it as complementary to the deficiency of the chimpanzee's pyramids.

Since the anterior pyramids are known to obtain a large portion of their fibres from the lateral columns of the cord, one might be inclined to refer this difference of the two pyramids to the difference between the respective lateral columns. But I find this explanation inadequate. Undoubtedly a considerable part of the discrepancy can be so accounted for, but not all. I find the fibres of the superior fine-bundled or sensory decussation to be remarkably fewer in the ape than in man. Consequently, if we suppose that less of the posterior column area decussates than in the human being, we shall understand why the posterior column remains larger than, while the pyramids fail to become as large as, the human.

That a relatively greater portion of the fibres of the posterior column in the chimpanzee must terminate in the nucleus cuneatus and gracilis will become evident as we proceed.

Apparently, the cebus monkey occupies a position intermediate between man and the higher ape; but if the originally defective character of the posterior columns (table A) be taken into account, it will become evident that the fibres of the pyramidal category are still more poorly represented in the posterior columns, while a relatively greater proportion terminates in the funicular nuclei.

The higher sections exhibit the origin of the olivary nucleus. In the similarity, nay, almost identity, of the shape, dimensions and relations of this body I find one of the strongest resemblances to the human being. As my views on the origin of the olivary body, and especially the relations of the internal accessory olive, differ from those accepted by the majority of writers, I refer the reader to an earlier article * in the JOURNAL OF NERVOUS AND MENTAL DISEASE for an explanation of the doubtful points.

The internal accessory olive is first struck on section in the upper half of the sensory decussation; its appearance is exactly like that of the human being; and, like the latter, it seems to rise out of the reticular formation at the point where the latter abuts on the pyramidal area. In the cebus, this body does not appear until the sensory decussation begins to undergo the transition to the restiform crossing, and differs markedly in other respects to be alluded to.

As in man, the accessory olive joins the vertical cell mass, developed on the outer border of the remnants of the anterior funicle; and at the same altitude in which, in man, the nucleus dentatus (body of olive) occurs, it also is seen in the chim-

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* "The olivary body in man, the anthropoids and higher animals." October, 1878.

panzee. First, a single dentation of this nucleus is struck in the altitude of the beginning restiform crossing, and in the next sections the olive proper shows five dentations. In man these dentations are usually so much acuter than in the chimpanzee that they are capped off separately by the knife. In my specimens from the chimpanzee, this occurs with one dentation, but on one side only.

Where five dentations are struck, two of them show secondary foldings.

I will now follow up the appearance of the olive on successive sections, and dispose of this part of the subject before resuming the description of the entire sections. In the altitude where the central canal communicates with the posterior fissure by a slit, the olivary nucleus proper shows an upper richly and sharply crenulated line, with three fundamental folds. The two inner are as yet simple, but the outer is dendritic, and sends out a long process, which is turned on itselt and reflected along the lower outer border of the main part of the olive. This latter is simple, showing only two folds. Where the lower hypoglossal roots appear, the nucleus dentatus has five main dentations; but, reckoning all the foldings, there are from ten to thirteen on the entire contour. In these sections the external accessory olive is faintly indicated, while the internal sends from its upper end a sharply recurved process, which, as we pass up in the series of sections approaches the lower lamina of the nucleus dentatus.

In the region where the posterior end of the fourth ventricle is struck, the latter body is of so complicated a structure that what I term primary dentations are no longer distinct, being split up by secondary folds: there are seventeen folds in all. This number falls to fifteen and thirteen in the next section, but in the altitude of the vagus roots rises to twenty-one on one side, nineteen on the other. At the lower end a number of folds are so sharp as to have separated from the main body of the nucleus in one section. The recurved fold of the inner accessory olive has nearly joined the main nucleus, and the outer accessory nucleus is now well marked, but is separated from the upper lip of the *hilus olivæ*, as in man.

Twenty-one* folds is the highest number reached; it begins to sink slowly from the time that the hypoglossal nucleus diminishes, while the internal accessory olive entirely disappears by the time the auditory root level is reached. Here there are fifteen folds. Now this number rapidly sinks; within the full breadth of these roots it becomes seven, then four, and remains so to above the root. At the same time the outer accessory olive diminishes and is fused with the upper lip of the hilus. The area of the nucleus dentatus has become immensely reduced, and while at the posterior pons border there are still three folds, enclosing a completely circumscribed cavity, at the point where the abducens roots (enclosed by pons fibres) begin to enter the medulla proper, a single mass surrounded by a molecular halo, and without a central space, is all that represents the olivary body. Before the abducens facialis field is reached it has entirely disappeared.

The following table will give a better idea of the differences between the human and anthropoid olive than any description:

TABLE C.

Altitude.	MAN.†	CHIMPANZEE.	CEBUS.
1.	Internal accessory nucleus appears.	Internal accessory nucleus appears.	No trace of olivary nuclei.
2.	Nucleus dentatus appears faintly.	Nucleus dentatus appears faintly.	Internal accessory olive appears.
3.	Nucleus dentatus, in five distinct masses.	Nucleus dentatus in two distinct masses.	Nucleus dentatus faintly indicated.
4.	These are reduced to three masses, each with three or four secondary folds. External accessory olive absent. Internal accessory olive well developed.	7 dentations on three fundamental folds. External accessory olive absent. Internal accessory olive well developed.	Nucleus dentatus a simple triangular area. The external accessory olive appears, and is united to the internal accessory olive for a short distance.
5.	Nucleus dentatus in *a* has 13 folds; in *c*, 21. External accessory nucleus faintly indicated.	Nucleus dentatus has 13 folds. External accessory nucleus faintly indicated.	Nucleus dentatus has two folds. External accessory nucleus in full development.

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* In a previous publication referred to I have given fifteen as the number. This was before I had examined an entire series of specimens.

† In this and the following table, the letters *a*, *b*, *c* and *d* refer to different individuals, sections from whose medullas were selected to show the range of difference in man.

Altitude.	MAN.	CHIMPANZEE.	CEBUS.
6.	Nucleus dentatus has 17 folds in *a*.	Nucleus dentatus has 17 folds.	Nucleus dentatus, 2 folds.
7.	Nucleus dentatus has, *a*, 19; *b*, 24, and *c*, 28 folds. External.	Nucleus dentatus has from 13 to 15 folds.	Nucleus dentatus, 2 folds. The internal accessory olive begins to disappear.
8.	Nucleus dentatus has, *a*, 18; *b*, 19 folds. Internal accessory olive begins to disappear.	Nucleus dentatus has 21 folds. Internal accessory nucleus well developed.	Nucleus dentatus, 2 folds. Internal accessory nucleus absent.
9.	Nucleus dentatus: *a*, 16; *b*, 18; *c*, 24 folds. Internal accessory nucleus almost absent.	Nucleus dentatus 17 folds. Internal accessory nucleus begins disappearing.	Nucleus dentatus, 2 folds. Internal accessory nucleus remains absent.
10.	Nucleus dentatus: *a*, 12; *c*, 23 folds. Internal accessory nucleus absent.	Nucleus dentatus has 15 folds. Internal accessory nucleus absent.	Nucleus dentatus has 3 folds. External accessory nucleus begins disappearing.
11.	Nucleus dentatus has, *b*, 9 folds. No accessory nuclei present.	Nucleus dentatus has 7 folds. No accessory nuclei present.	Nucleus dentatus a single mass. No accessory nuclei present.
12.	Nucleus dentatus, in *b*, 9; in *c*, 13 folds.	Nucleus dentatus has 4 folds.	All the olivary nuclei absent.
13.	Nucleus dentatus has, in *c*, 7 folds.	Nucleus dentatus a single round mass.	As above.
14.	All the olivary nuclei absent.	All the olivary nuclei absent.	As above.

In order that the reader may be able to compare herewith the dimensions of the area of the nucleus dentatus, I have compiled the following table, in which the whole area of the medulla is taken at 1.0000, the standard figure which applies in this essay to the total area of sections in any altitude :

TABLE D.

	Altitude 5.	Altitude 7.	Altitude 10.	Altitude 12.	Altitude 18.
Human, (*a*)	.0962	.1361	......	.0154	.0206
" (*b*)	.1110	......	.2106	......	......
" (*c*)	.1406	.1458	.1428	.0610	trace
" (*d*)	......	......	.0554(!)	......	......
Chimpanzee	.1006	.1270	.1384	.0240	.0160
Baboon	......	.0778	......	......	......
Cebus	.0240	.0705	.0526	absent	absent

In these tables altitude 1 refers to the latitude of the sensory decussation; 2, to the beginning restiform decussation; 3, the obex; 4, the same higher; 5, the lowest hypoglossal roots; 6, the hypoglossal nucleus in its full breadth; 7 and 8, higher altitudes of same; 9, the disappearing hypoglossal nucleus; 10, the *striæ medullares;* 11, the full auditory root; 12, the lower border of the pons; 13, two millimetres above this border; 14, the abducens roots where seen in their full length. It is needless to add that in the cebus altitude 12, 13, and 14, correspond to the trapezium and not to the pons.

While the olive is so closely similar to the human in its dimensions and shape, it is exactly like it in its histological structure; the thickness of the olivary lamina is, however, somewhat less, bearing a proportion of from three-quarters to seven-eighths of the thickness of the human olive. In lower animals, even in the Old and New World monkeys, the internal accessory olive bears an inverse ratio to the nucleus dentatus; where the latter is rudimentary, the former is massive, and absolutely in all these animals, while the nucleus dentatus is far inferior to the human, the internal accessory is superior. In the chimpanzee the latter is as attenuated as in the human being.

The restiform decussation is not so extensive in the chimpanzee as in man. The fibres are fewer, though their arrangement is the same. This fact bears an evident relation to the deficiency of the restiform column which is observed in higher altitudes, and regarding which there is a greater gap between man and the chimpanzee than there exists in regard to the anterior pyramids.

As we progress upward through a series of sections of the medulla, we observe that the funicular prominences are not as bold as in man, while the ventricular ponticulus is somewhat thicker, but when we proceed to measure the various diameters we will find their mutual proportions strikingly human-like. It may be accepted as a law in cerebral anatomy, that the more voluminous the cerebrum and cerebellum (for both, contrary to a popular opinion, keep pace to a certain extent) the greater will be the vertical diameter of the medulla; and of the two transverse diameters, one being taken through the restiform, and the other through the greatest width of the olivary region, the former will preponderate as we pass up in the scale.

In the following table, these dimensions have been arranged in various successive altitudes, the numbers of the latter corresponding to those in table C. The dimensions are given in millimetres :

TABLE E.

Altitude.	1.	4.	5.	6.	8.	10.	12.
Height of Raphe in Man........	6.	$7.^{5}$	8.	$9.^{6}$	13.	14.	$12.^{3}$
In Chimpanzee................	$4.^{5}$	$4.^{7}$	7.	8.	10.	$9.^{5}$	$9.^{8}$
Height of Medulla in Man.......	14.	$17.^{5}$	17.	$15.^{5}$	$17.^{5}$	18.	17–19
In Chimpanzee................	$11.^{2}$	11.	12.	12.	$12.^{2}$	$12.^{2}$	13.
Transverse diameter through Restiform region in Man..........	15.	17.	18.	18.	23.	25.	25–29
In Chimpanzee................	13.	$13.^{5}$	$14.^{5}$	$15.^{5}$	16.	$19.^{2}$	$19.^{5}$
Transverse diameter through Olivary region in Man...........	11.	$14.^{5}$	$16.^{5}$	16.	18.	19.	$14.^{5}$
In Chimpanzee................	10.	10.	12.	13.	$12.^{5}$	12.	9.

In this table we observe that the raphe progresses in about the same ratio in man as in the chimpanzee, and that in both the greatest increase is in the same altitudes of the upper hypoglossal roots and the striæ medullares (8–10).

The total height of the medulla does not increase as rapidly as in the human being, though it reaches its maximum at the same point (12). From this it follows that the further we pass from the decussation to the pons, the flatter does the chimpanzee's medulla become as contrasted with that of man ; this approximation to the lower animals is however still more pronounced in the baboon and lower monkeys.

While the transverse diameter taken through the restiform region maintains the human ratio and proportion, that taken through the olivary body does not progress as quickly, and reaches its highest point (6) earlier than in *most* human medullas (10); this latter feature corresponds to the observation deducible from table C, namely that the point where the human olive *usually* shows the most intricate folding is on a higher altitude than the corresponding point in the chimpanzee, or rather that the intricacy of the dentations of the olive as well as its dimensions fall more rapidly in the anthropoid than in man (table D).

If we now suppose the total vertical diameter of the medulla oblongata to measure 100, and compare the proportions which the two transverse diameters bear to this standard in man, the chimpanzee and two lower monkeys, selecting the same altitude (8) of the hypoglossal roots in each, we obtain a result strikingly confirmatory of the correctness of the final conclusion to be announced :

TABLE F.

	Man.	Chimpanzee.	Baboon.	Cebus.
Vertical Diameter	100.	100.	100.	100.
Diameter through Restiform Columns	132.	131.	142.	133.
Diameter through Olivary Eminence	102.	102.	100.	96.

In higher sections the discrepancy between different human individuals in regard to these proportions becomes very great: in one medulla the flatness appears greater than even in the chimpanzee, but in reality this was an absolutely high medulla, with such immense restiform columns that the vertical diameter was relatively reduced. Within the area of the auditory roots, the proportion of the chimpanzee's bi-restiform diameter to the vertical is 150 : 100, in man 147 to 170—100, in the cebus 180 : 100 ; this latter measurement is dependent on the actually great reduction of the vertical diameter, due in its turn to the defective pyramids, and the real discrepancy is much greater than the figures show, on account of the extreme reduction of the restiform column.

On comparing a section from the chimpanzee's medulla, taken through the lowermost hypoglossal roots, with a corresponding section from the human, we notice, first, that the contour of the olivary eminence is less marked ; that the angle at which the internal accessory olive is bent (which is nearly a right-angle in man) is obtuse ; * and that the fibres of the pyramids, which in man are already cut obliquely, on account

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* This angle is the wider the lower we go in the scale ; as the lower side of the angle necessarily follows the contour of the pyramid, it must become more and more driven up as the latter rises in development.

of the approaching decussation, are still to a slight extent vertical. The hypoglossal nucleus shows the same number and arrangement of the nerve cells found in man, and this is illustrative of a statement made on a previous occasion, that the innervations of speech in the human being do not require a more complex development of the lower automatic centres than is found in speechless animals. From this it follows that the same amount of grey matter can be under a lesser or greater multilocular subjection to co-ordinations and associations pre-existing in the highest centres: the nerve nuclei seem to follow in their mass—not the complexity of the function they subserve, but the size of the area to be innervated from them.

The proportions of the most important areas to the entire area are as follows:

Area of pyramid	.1111
" internal division of reticular field	.0432
" ascending V. root	.0092
" nucleus hypoglossi	.0308
" restiform remnant	.0493
Proportion of pyramid to internal division of reticular field (taken as 1.0000)	2.5706

In the higher series of sections we observe the same distribution of nerve nuclei, and as large a fasciculus teres as in man. The ascending quintus root is more crescentic, the human more oval in this region. Another difference is that the *stratum zonale* is half as thick again as that of the ape. This is, doubtless, to be interpreted as connected with the relative deficiency of the chimpanzee's restiform column, as it is well known that the *stratum zonale* derives its fibres from this column. The measurements are as follows:

TABLE G.

	Man.	Chimpanzee.
Proportion of anterior pyramid	.1555	.1111
Proportion of interior division of peduncle	.0666	.0761
Proportion of pyramid to internal division of peduncle; the latter taken as 1.0000	2.3348	1.4599

I find, on comparing a number of human medullas, that in the altitude of the middle olivary region the anterior pyramids vary from .1050 to .1750; in the same sections the chimpanzee has .0825, the cebus .0500.

Where the human restiform column measures .2190, that of the chimpanzee is but .1310. This discrepancy becomes more and more manifest as we proceed towards the cerebellum. Probably the lesser amount of zonal fibres and the rudimentary condition of the *nuclei arciformes* is hereunto related.

The auditory nerve root has the same intra- and extra-medullary nuclei as in man, and as in the latter, the fibres of the *striæ medullares*, or the superficial root fibres, extend to the raphe. Higher up there are seen fibres of this nerve running through the reticular field to the raphe, and for which, in the case of man, I suppose they represent a raphe projection to the cerebrum, differing with Meynert, who considers them to be a decussated set of cerebellar radicles.

In these altitudes the pons fibres begin to clasp the pyramids, a little asymmetrically, and include the emergent abducens nerve root. Now, while the pons, as stated in the macroscopic description, extends entirely as far downwards as in man, and therefore one essentially human feature is characteristic also of the anthropoid, yet there is a great discrepancy in the amount of pons fibres struck at the lower edge of this body. These are from three to four times as voluminous in man. As we proceed upwards, however, this discrepancy becomes gradually reduced. At one point, in fact, the chimpanzee reaches a higher figure than one human specimen.

TABLE II.

Proportions of pons to entire area of transverse section, exclusive of those portions which are properly cerebellar in their topography.

	Man.	**Chimpanzee.**	**Cebus.**	**Dog.**
In region of emerging abducens root	.2051	.0588.	none.	none.
In region of lower facial nucleus	.3710	.2870.	trace.	none.
In region of common abducens facial nucleus	(*a*) .4871 (*b*) .6470.	.5009	.2273	none.
In region of lingula cerebelli	(*a*) .7276 (*b*) .8000	.6923	.2980	.1190

In the region of the trochlearis roots the discrepancy between the human and anthropoid pons again manifests itself, but to a much less degree than in the lowest altitudes.

The brachium conjunctivum (*processus e cerebelli ad cerebrum*) bears the same ratio to the entire tegmentum that it does in man, and with this we find further on a well developed nucleus tegmenti, which rivals the human in size and is of the same histological structure.

We now have arrived at that region in which, according to Meynert, the proportions of the fibre masses subservient to the intelligence can be best ascertained, as contrasted with the fibres and ganglia concerned in automatism. It is well known that the *pes* or *basis* of the crura stands out more or less prominently in different individuals: in some it is flat and broad, in others narrow and high, and in still others as broad as in the former and as high as in the latter. This third condition I have found especially associated with well convoluted hemispheres, although I do not mean to imply the converse, that well convoluted hemispheres always must be associated with a large *pes pedunculi.**

Here the chimpanzee occupies a rather intermediate position, and here is the first point in which a marked histological difference from man is noticeable.

The cells of the substantia nigra are imbedded in a molecular mass, which encroaches on the area of the pes pedunculi by sending out anastomosing processes, which isolate the peduncular fibres that adjoin this substance. In the chimpanzee this substance is at least twice as voluminous as in man, and as in addition to this encroachment on the pes pedunculi, its whole area is smaller, its absolute bulk is below that of the human being, though on the other hand far above that of lower animals. I estimate it as follows:

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* I believe that many insanities, as well as many conditions allied to insanity, such as the hysterical and "blue-stocking" propensities, may yet be traced to an inadequate projection of a well developed hemisphere. I have announced a similar view in an unpublished essay on the Somatic Etiology of Insanity. The development of powerful peduncular tracts demands certain proportions of the base of the cranium, as a *conditio sine qua non*, and as these latter proportions are more apt to be deficient in the female sex, this may explain the preponderating prevalence of the two conditions named in that sex. It is certainly suggestive in relation to this question, that males suffering from analogous forms of mental perversion, should have similar peculiarities of the cranium. In the female these peculiarities are normal, and exercise a prejudicial influence only when the hemispheric development exceeds the healthy average; in the male they signify a tendency to degeneration, a lack of harmony between cerebral and cranial development, resulting from the enervating influences of city and sedentary life. A good physique, associated with a cranium whose ridges are prominent and whose foramina and inner recesses are well marked, is rarely if ever co-existent with the mental conditions referred to.

In man, from .3128 to .5219.
In chimpanzee, .2860.
In cebus, .1100.
In dog, .0632.

The nucleus tegmenti is, if anything, larger than in man, is as sharply demarcated and (as previously stated) of the same structure as in the human being.

The interpeduncular ganglion, which is large in the rabbit, dog, and other lower animals, is rudimentary as in our own species. The ganglion Sœmmeringii is rich in large multipolar cells, in a few of which there is a faint and doubtful indication of pigment. The central tubular grey matter and other masses are identical with the human, the corpora quadrigemina are however larger; I should say relatively to the human they stand as nine to eight.

In altitudes higher than the corpora mammillares I have not been able to carry on the investigation on account of the fragility of the tissues.

Summing up our results, we find first that in respect to the peduncular tracts, the anthropoid apes stand nearer to the human species than any other animal yet examined.* Secondly, that the differences between man and the anthropoids are less than those existing between the latter and the baboon, macacus, cebus, lagothrix, semnopithecus or cynopithecus.

I leave it an open question whether the ateles may not approximate the chimpanzee in regard to the olivary body, while I can state that it is far below the latter in the development of the pons.* With reference to the gibbons, which animals I do not class among the anthropoid apes, but intermediate between the latter and semnopithecus, I have no specimens for comparison. Judging by a figure from Bischoff, in which the peduncle is represented as cut through, I should suspect them to be nearer to the ordinary Old World apes than to the anthropoids in respect to the basilar tract.

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* In addition to using the measurements and diagrams of animal pedunculi, furnished by various authors, I have measured the tracts of numerous monkeys, the elephant, seal, bear, and other animals whose hemispheric development is not as great as in the three named.

In the development of the nucleus dentatus of the olive, in the preponderance of the pes pedunculi, the vertical pons fibres and the anterior pyramids, man and the anthropoids *together* possess characters separating them from all other animals. In the reduction of the molecular grey matter, by which the area of the strands connected with higher automatic and intellectual centres is inversely increased, we notice another striking parallelism between the two.

As one result of our inquiry, which may aid in solving some of the difficulties of human cerebral anatomy, I would point to the fact, that the restiform column of the chimpanzee is far inferior to that of man, while the brachium conjunctivum with its nucleus is as large or larger. In the first place this is confirmatory of the older supposition that the inferior and superior cerebellar peduncles are independent systems; in the second, it shows that the projection of general sensation through the upper peduncle (brachium conjunctivum) as well as of motility direct, is excluded, therefore these parts can be subservient only to associating, or to vaso-motor influences.

If we were to represent the average development of the higher (hemispheric and cerebellar) tracts of the human being as 100, the chimpanzee would rank about 75, the baboon at 40, the cebus at 25, the dog at 7½.

One point observed, the close approximation of the area of the posterior columns in the chimpanzee and man, as contrasted with the great inferiority of these columns in lower animals, opens a question as to the relation between the development of the posterior columns and the hemispheres. Our results corroborate Meynert's statement, that the superior pyramidal decussation is derived from these columns (against Flechsig), and the existence of a path of conscious sensation from the posterior columns to the posterior part of the internal capsule, is still to be maintained.

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* Although the trapezium seems to be perfectly covered.

Now, the development of the higher intellectual faculties rests in great part in the readiness and complexity of sensory appreciation, therefore *cæteris paribus*, the area of the posterior spinal funiculi in the cervical region would, like the area of the pes pedunculi, be an index of cerebral development.

The remarkably rudimentary condition of these columns which I have observed in turtles, frogs, the menobranchus and snake,* as well as the gradual rise in their area as we pass from these through the lower to the higher mammalia, is strongly in favor of the above view.

In many respects the present article is merely a preliminary communication, and I shall therefore refer only briefly to one other result which was obtained. If, of a series of sections from a human medulla, two be selected—one just above, the other just below the roots of the hypoglossal nerve—a considerable difference will be found in regard to the area of the anterior pyramids. This difference is evidently due to fibres which have been given off through the raphe to the hypoglossal nucleus, placing the latter under the cerebral control. In the chimpanzee this difference is not even approximately as great, a fact which furnishes in my mind a more logical explanation (anatomically) for the absence of speech in the anthropoid than the popular but fallacious reference to the presence or absence of an inferior frontal convolution, or of gyri on the island of Reil.

In this single respect the human peduncle stands alone, and a chasm separates it from all others; but he who has studied the course of development followed by the cerebral fibres, will recognize in the rectilinear strands of the *raphe medullare* that potentiality of the speech function which our pithecoid ancestry must have possessed, and in no higher grade than the existing anthropoids, before this function became actually established.

While this latter inference is made in accordance with the prevailing views as to the ancestry of man, I refrain from pursuing a theme which, however interesting, enters on the domain of the speculative.

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* Also noticed in the specimens from the alligator demonstrated by Dr. Mason before the American Neurological Association.

The advocates of the doctrine of evolution will perhaps be able to formulate some conclusions on the facts of this paper which will support their views in regard to the relations of man to his problematical ancestry, as well as to the collateral descendants of the latter.